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THE DOD'S ALTERNATIVE FUEL POLICY

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE

by

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This thesis examines the question of the scarcity of petroleum-based fuels early in the Twenty-First Century and the DOD policy and programs to meet this shortage. Based on the fact that petroleum fuels as we know them will not be availabe early in the Twenty-First Century, this study examines the uniqueness of the DOD's world-wide mission and its dependence on petroleum fuels for its main weapon systems. Because of this uniqueness, it was concluded that the DOD needs an alternative fuels

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policy independent of other governmental agencies to meet the national security requirements. The current DOD policy on alternative fuels for the future is examined. This investigation revealed that, as of January 1978, the DOD did not have a comprehensive policy for alternative fuels. Further, the direction of Research and Development efforts has suffered as a result of this lack of policy. Lastly, the study offers a proposed policy for consideration. Recommendations for both short- and long-range goals are proposed. Conclusions were that an alternative fuels policy is absolutely necessary and that a policy needs to be established as soon as possible.

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This thesis examines the question of the scarcity of petroleum-based fuels early in the Twenty-first Century and the DOD policy and programs to meet this shortage. Based on the fact that petroleum fuels as we know them will not be available early in the Twenty-first Century, this study examines the uniqueness of the DOD's world-wide mission and its dependence on petroleum fuels for its main weapon systems. Because of this uniqueness, it was concluded that the DOD needs an alternative fuels policy independent of other governmental agencies to meet the national security requirements. The current DOD policy on alternative fuels for the future is examined. This investigation revealed that, as of January 1978, the DOD did not have a comprehensive policy for alternative fuels. Further, the direction of Research and Development efforts has suffered as a result of this lack of policy. Lastly, the study offers a proposed policy for consideration. Recommendations for both short- and long-range goals are proposed. Conclusions were that an alternative fuels policy is absolutely necessary and that a policy needs to be established as soon as possible.

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CHAPTER 1

DWINDLING ENERGY RESOURCES

The Study

STATEMENT OF THE PROBLEM: The era of abundant fossil fuels is rapidly drawing to a close. With this fact as a basis, the Defense Department, with its extensive demand for petroleum-based fuels for mobility, needs an alternative fuel policy to meet this imminent danger, and to carry the defense establishment into the 21st century.

GOAL OF THE STUDY: To evaluate current Defense Department alternative fuels policies, and identify any areas that may not be addressed by current policy that affect a viable defensive posture both in the near and long term. If, as a result of this study, shortcomings are identified, recommendations will be made as to the direction that might be taken by the Department of Defense (DOD) to overcome those deficiencies.

METHODOLOGY: In developing this report; unclassified research reports, technical reports, and memorandum reports, supplemented by telephone surveys of energy experts were compiled. Both industry and governmental agencies were surveyed in the area of energy policy, and developing technology.

Background

Convenient fuels such as natural gas and petroleum are a finite commodity, i.e. they will not last forever.

They represent only 3 and 4% of the earth's estimated total reserves, but account for approximately two-thirds of the energy used in the United States. This is expected to decrease to 40% by 1990, and by 2000 we will have only 25% of today's reserves remaining! Therefore, the problem is not one of cost alone, but the fact we are not going to have convenient petroleum-based fuels available in the not-so-distant future.[1]

The first major public governmental stand on energy came on June 4, 1971 when President Nixon delivered an energy address to Congress in which he stated:

> A sufficient supply of clean energy is essential if we are to sustain healthy economic growth and improve the quality of our national life. I am, therefore, announcing today, a broad range of actions to ensure an adequate supply of clean energy for the years ahead. Private industry, of course, will still play a major role of providing our energy, but government can do a great deal to help meet this challenge....[2]

The energy dilemma was brought into sharp focus during the 1973 oil embargo. Many programs have been initiated in an attempt to ease the energy situation. President Nixon started "Project Independence" which had a goal of self-sufficiency by 1980.[3] On the 29th of June 1973, President Nixon announced several actions his administration was taking to solve the nation's energy problems and long-term needs. In this announcement he stated:

> Now we must build on our increased knowledge, and on the accomplishments of the past twenty-two months to develop a more comprehensive integrated national energy act to conserve energy more effectively; strive to meet our energy needs at the lowest cost consistent with the protection of both our national security and our natural

environment; reduce excessive regulatory and administrative impingements which have delayed or prevented construction of energy-producing facilities; act in concert with other nations to conduct research in the energy field and to find ways to prevent a serious energy shortage; and apply our vast scientific and technological capacities, both public and private, so we can utilize our current energy resources more wisely and develop new sources and new forms of energy.

The actions I am announcing today and the proposals I am submitting to Congress, are designed to achieve these objectives. They reflect the fact that we are in a period of transition in which we must work to avoid, or at least minimize, short-term supply shortages, while we act to expand and develop our domestic supplies in order to meet long-term energy needs.

We should not suppose this transition will be easy. The task ahead will require the concerted and cooperative efforts of consumers, industry and government.[4]

Congress has been deluged with various energy-saving and energy production plans. A cabinet department was formed to deal with energy matters. Many programs have been initiated since 1973. It is now time to ask several questions to evaluate where we are, where we are going, and how effective these past programs have been.

Where do we stand on the goal of self-sufficiency?

How much oil and gas remain undiscovered?

How much of that oil is economically recoverable?

What new extraction techniques will become economically feasible as the supply demand cycle drives prices up?

How much can our vast coal reserves replace dwindling oil and natural gas?

Just how rapidly can nuclear energy be expanded to meet a major source in our power needs?*

*Note: These questions were asked by the editorial staff of the Kansas City Star on 27 September 1977. No answers were offered.

Figure 1 demonstrates graphically the situation today. In the winter of 1976-77, for example, gas was cut off to industry in many parts of the country as demand exceeded supply due to the severe winter cold. Residential consumers received the highest priority, therefore, many businesses were forced to close, resulting in layoffs and massive unemplyment. This had considerable effect on our gross national product. Some estimates place it in the billions of dollars.

Our consumption of oil in January of 1977 was over 19 million barrels per day. Over half of this came from foreign sources and cost the United States 4 million dollars every hour of the day for 365 days. This multiplies out to $2,880,000 per month. What effect is this having on our balance of payments and the strength of the dollar throughout the world? One effect was an announcement in December 1977 that the Federal Reserve would be taking steps to support the dollar in the international monetary market. If this monetary deficiency isn't corrected, it could lead to economic collapse of the dollar. To further complicate the situation, some of our chief suppliers, such as Canada who supplies both gas and oil, have begun a cut back schedule which calls for a stop in exports to the United States by 1982--only four years from now. Another, Venezuela, had also ordered cut backs on shipments. These cutbacks will leave the United States almost totally dependent on the Middle East for its energy demands, making us even more vulnerable to an embargo than we were in 1973.[5]

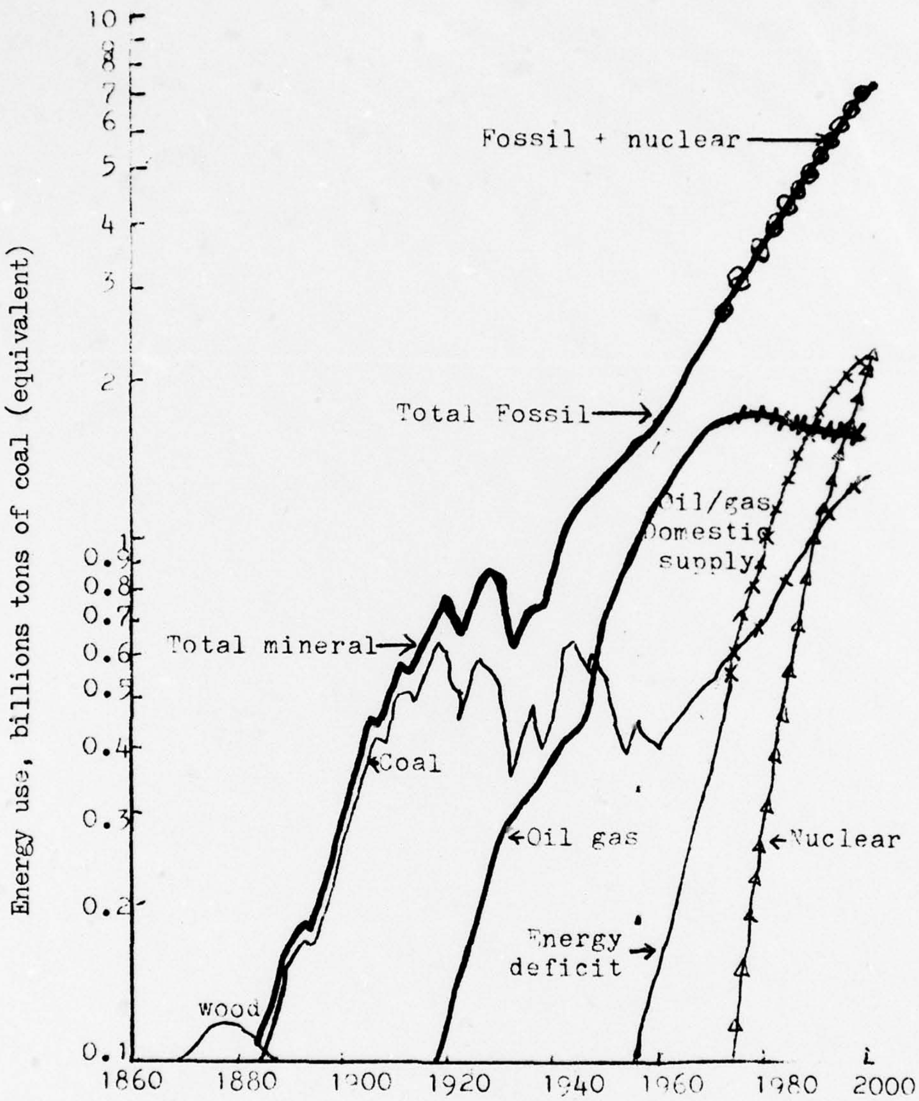


Figure 1

A panorama of fuel use in the United States 1860 to 2000[a]

a. Ralph E. Lapp, Science and Public Affairs (Bulletin of the Atomic Scientists), Vol. XXIX, No 7, pp. 8-14, September 1973.

Most of the scientists and energy experts agree that the United States will not be able to achieve self-sufficiency by 1980.(See Figure 2) It is unlikely that independence can be accomplished even by 1990.[6] Many proposals to correct this situation appear in the press daily. These sources of energy are presented as the answer to the energy supply problems. Fuel cells, methane from manure, new wind-driven turbines, solar heating and cooling, are but a few of the many sources which can be explored. What is ignored, or at best unappreciated, is the miniscule energy contributions of such inventions, which, if successful would only make a small contribution to meeting the total energy demands of the nation for many years to come. The lead time is extensive and requires large investments today for returns that may not be realized for ten or fifteen years.

The Defense Department seems to realize the seriousness of the situation as indicated by statements recently made by Secretary of Defense Harold Brown:

> Two thirds of all the oil ever used has been consumed in the past seventeen years. Virtually all the world's consumption of natural gas has occurred since 1945. As we compound our consumption at an annual growth rate of 3.5 percent, our reserves decline. Arguments that reserves remain to be discovered fail to take into account the numbers. To maintain even the present rate of consumption without eating into our reserves, we would need to discover another Texas or Alaska every six months; or an Iran or Kuwait every three years. That is not going to happen.[7]

There is debate within the sciencific community on what direction energy research should take. But the one fact on which all agree is that our nation and even the world will

Figure 2

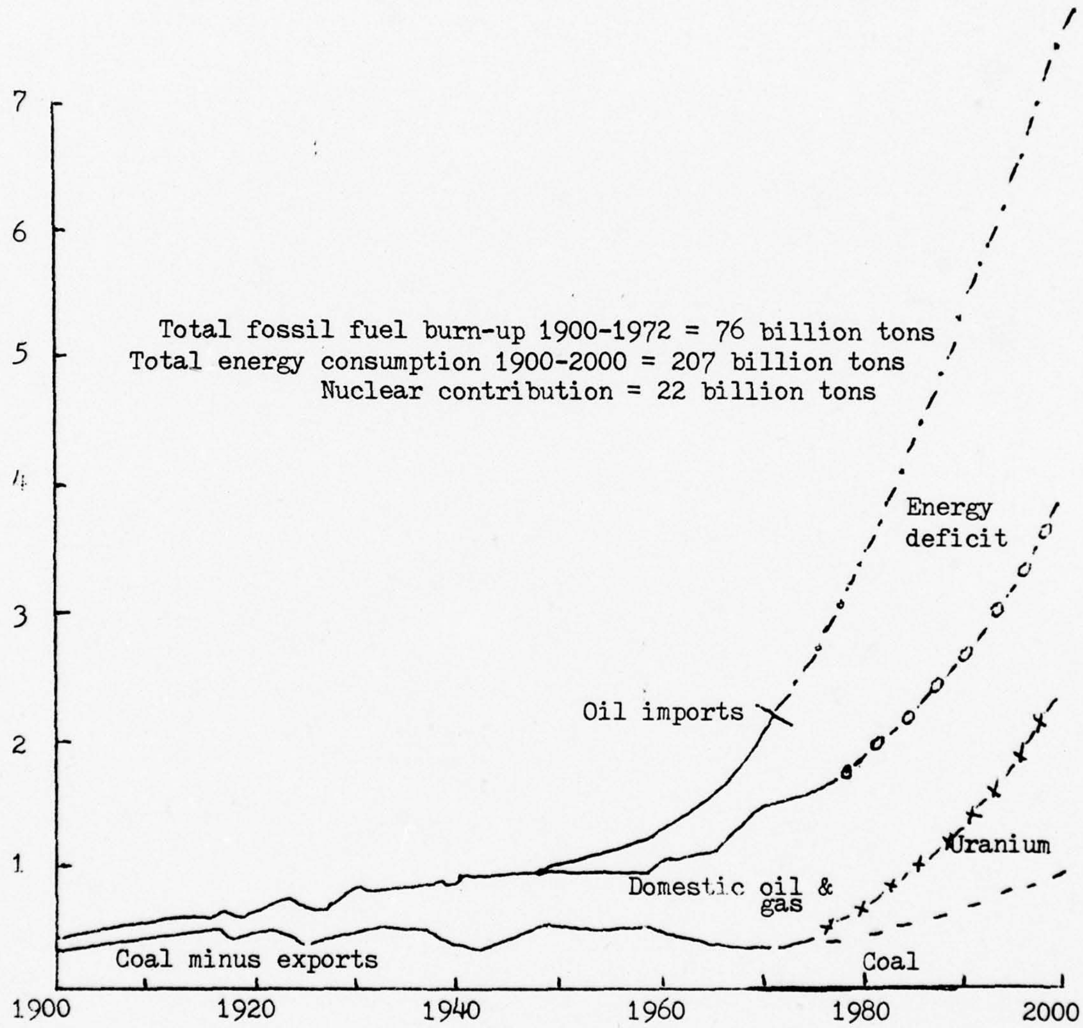


Figure 2

Profile of U.S. fuel use, 1900-2000[b]

b. Ralph E. Lapp, Science and Public Affairs (Bulletin of Atomic Scientists), Vol. XXIX, No 7, pp. 8-14, September 1973.

not have petroleum in the not-so-distant future. This being the case and recognizing the impact that the lack of fuel would have on the mobility of our armed forces, the questions that must be answered are:

In light of the efforts being put forth by other agencies of the government, is there a requirement for the Defense Department to have its own alternative fuels policy?

If it is necessary, what is that policy; and does it meet the challenges posed by the imminent conventional fuel shortage?

REFERENCES

[1]Robert Gillette, "Energy R&D: Under Pressure, A National Policy Takes Form," Science, Vol. 182, No. 4115, (November 30, 1973).

[2]Roger C. B. Morton, "The Nixon Administration Energy Policy," American Academy of Political and Social Science Annals, Vol. 410 (November 1973), 66-67.

[3]Richard M. Nixon, "Nixon's Blueprint for Meeting the Energy Crisis," U.S. News and World Report, Vol. 75, No. 21 (November 19, 1973), 116.

[4]Ibid, 67-68.

[5]USAF Alternative Energy Panel, "An Assessment of Solar Energy As A National Energy Resource," PB-221659 (December 1974), 11.

[6]Ibid, 11.

[7]Opinion expressed by Harold Brown, Secretary of Defense, in an address at the Council for Financial Aid to Education in New York, October 26, 1977.

CHAPTER 2

THE NEED FOR A DOD ALTERNATE ENERGY POLICY

National Security

READINESS: The military is already feeling the effect of the fossil fuel shortage. As supply decreases and demand increases, prices are rising at astronomical rates. These increases in fuel cost have had an effect on readiness. As our convenient fossil fuels are depleted, the price is increasing to the point that it is affecting our national security. The Air Force is using 30% less fuel today than it did five years ago, but the cost now is two and one-half times more for that fuel.[1] This is also true of the Army, as all of its main firepower weapon systems require petroleum-based fuel. The cost of fuel used in field exercises has reduced their number, causing training vehicles to be parked in storage areas. This leads to equipment problems such as hardened seals, deterioration of rubber components, leaks, and, thus, fewer combat-ready vehicles. The cost of fuel has reduced flying hours for both the Army and the Air Force. Pilots who are in non-flying staff positions no longer maintain flying proficiency. What effect this will have on future readiness has not been fully determined. The pilot production programs have been revamped. Fewer pilots are graduating from pilot training. When they do graduate, they no longer go to an advanced fighter school, but to an interim school where armed

trainers are used rather than advanced fighters. This policy resulted from an effort to save fuel and reduce costs. The relatively low fuel consumption of training aircraft when compared to operational aircraft was one step taken to save fuel. Upon completion of this training program, the pilots are then sent for a minimum check out in the major weapon system such as the F-15 or A-10. This reduction in experience produces a less qualified individual than under the old system where the pilot received all his graduate pilot training in the advanced weapon system that he was to operate in his unit. *

COMBAT REQUIREMENTS: The DOD is unique in that it has world-wide commitments. Its combat capabilities are totally dependent on petroleum fuels. Figure 3 demonstrates the gap between available fuel and the fuel required during combat. The following remarks were also made concerning the availability of fuels for combat purposes by the U. S. Army Fuels and Lubricants Research Laboratory (AFLRL).

1. The age of abundant low-cost petroleum fuel is over, and the current fuel shortages in CONUS will be followed by increasingly short world supplies.

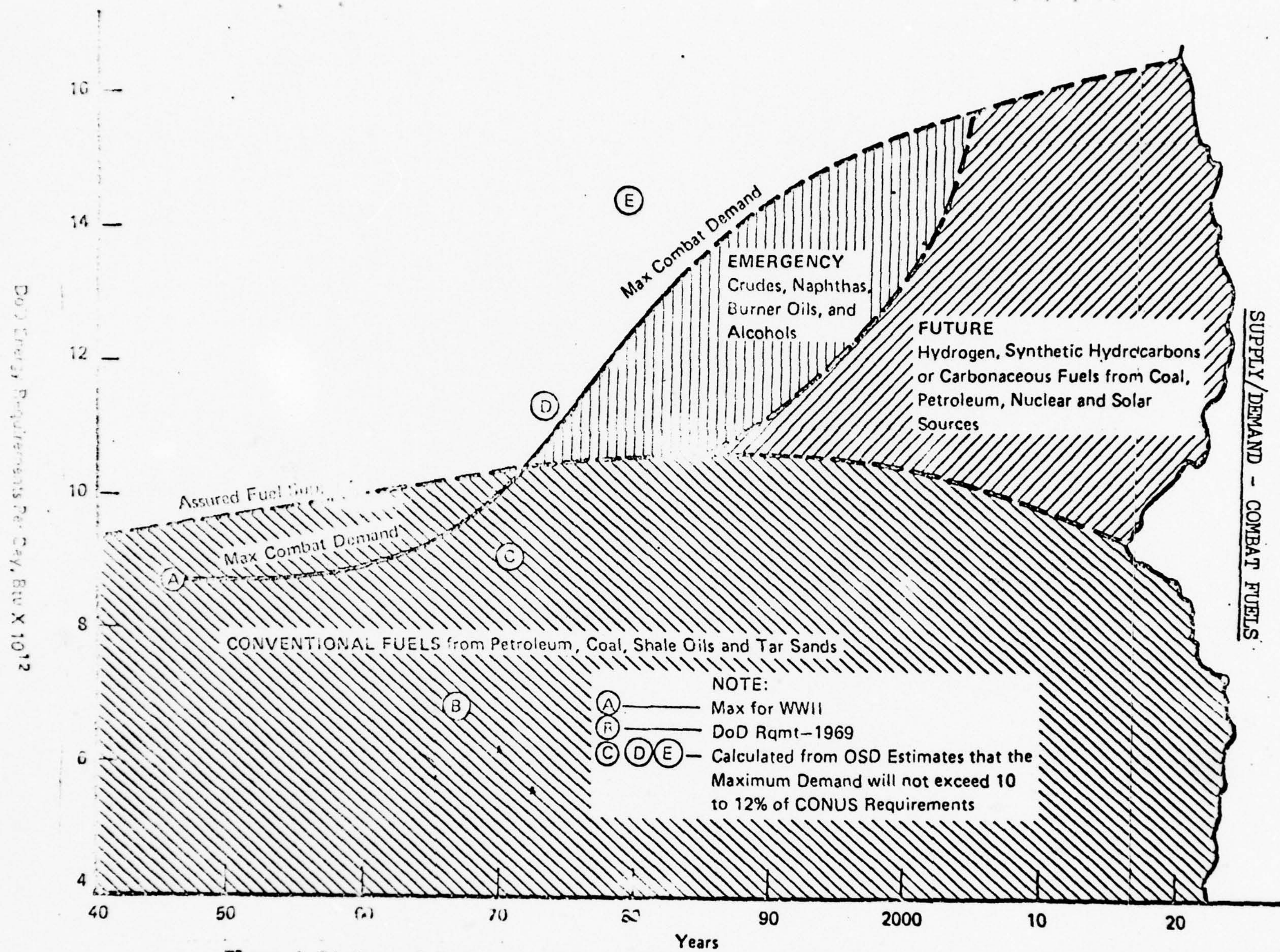
2. From a long-range viewpoint, CONUS and the world are now entering a period of transition from primary reliance on petroleum fuels for energy to primary reliance on nuclear, goethermal and solar energy sources. The transition will require several decades--well into the twenty-first century.

3. The progress of the transition will be a sequence of technological-economic events--i.e., the supply of petroleum fuels fails to meet demand; costs go up; other fuel sources and source processing methods become economically competitive; new energy sources and new fuels evolve.

*Note: Survey of experienced Air Force pilots attending Army Command and General Staff lead to this conclusion.

Figure 3

SUPPLY/DEMAND - COMBAT FUELS



Plans & Status of U.S. Army Energy R&D Program, U.S. Army Fuels and Lubricants Laboratory Paper, August 1974.

Revised August 1974

4. During the transition, the availability of fuels for combat will undergo periods of scarcity as will the availability of fuels for industrial and private consumers.

5. A combination of limited data (available to them in the early 1970's such as the unsatisfactory availability of fuels in SEA during 1971 and the shortage reported by DSA of fuels in CONUS) and strong circumstantial evidence (public statements by authorities in DOD to include Secretary of Defense Laird) indicates that the supply of combat fuels will be affected and sometimes be insufficient for our future mobility and electrical needs during some general and limited war situations.[2]

Our ability to carry out national policy world-wide is almost totally dependent on energy which requires extensive transportation by sea. The growth of the Soviet Navy and the shrinking size of our own naval forces leaves doubt whether or not these sources would be available in time of confrontation or hostilities. If this is the case, and our combat effort is so dependent on petroleum supplies, the obvious conclusion is that we already have reached a point where the lack of fuel supply could effect our national security.

OTHER FACTORS: Defense dollars are being consumed by fuel cost not directly related to combat readiness. This increased cost continues to have serious impact on security. Energy for heating and cooling military buildings now devours more of the defense dollar, thus reducing money available for hardware, training and overall readiness. DOD conservation efforts have decreased utility consumption rates by 17%, but the dollar amount to pay heating and cooling bills has more than doubled as shown in Table 1.[3]

Table 1[4]*

DOD MBTU use vs. dollar costs

Fiscal Year	MBTU	Dollar Cost
73	242	163
74	209	185
75	201	311
76	201	355

NEED FOR A POLICY: With the mission of the Department of Defense being so totally dependent on fossil fuels, it seems that this fact alone would require the DOD to have its own policy on alternate energy. When one considers that there is a high probability of inadequate world production and refining capacities especially in wartime situations; the probability of enemy action to reduce the supply line flow of petroleum; the fact that combat fuel will be in competition with fuel necessary to keep the nation's industrial base producing needed war materials; and the fact that domestic demand is increasing; the shortage will continue to grow to a point where even rationing will be unable to provide enough fuel for the combat machines required to maintain our national security. When you consider these collectively, the need for a Defense Department alternative fuels policy is evident.

It is also worth noting that treasury funds are as

*Note: Shows the number of BTU vs. the cost over a four-year period.

finite as fossil fuels, and that dollars spent by other government agencies on energy research are funds that are in direct competition with dollars for defense. Since the research and development efforts today will have direct effect on energy availability, cost, and overall readiness, and the ability of the DOD to meet its charter, an energy policy for the Defense Department is an absolute must.

REFERENCES

[1]NSF/NASA Solar Energy Panel, "An Assessment of Solar Energy as a National Energy Resource," PB-221659 (December 1972), 11.

[2]U.S. Army Fuels and Lubricant Research Laboratory (AFLRL), "Plans and Status of the U.S. Army Energy R&D Program," (August 1974).

[3]USAF Alternate Energy Workshop, AFIT School of Civil Engineering,Wright Patterson AFB, Ohio, (February 24-26, 1976).

[4]Ibid.

CHAPTER 3

THE DOD ALTERNATIVE FUELS POLICY

Present Policy

There is a genuine need for an alternative fuels policy in the DOD. Using this as an assumption, the next step is to determine what the present DOD policy is and if it meets the requirements demonstrated in the first two chapters. The initial search for information included a study of DOD documents--this search did not reveal an alternative fuels policy. A subsequent survey of DOD energy and policy experts was initiated to determine what the current DOD policy is regarding alternative fuels.

THE U.S. FUELS AND LUBRICATION LABORATORY: The Fuels and Lubricants Division is a subdivision of the Energy and Water Resources Laboratory, located at the U.S. Army Mobility Equipment Research and Development Command at Fort Belvoir, Virginia. They are chartered by the Army to fulfill needs in the area of research and development generated by the requirements of the Army's Training and Doctrine Command. They are not the policy makers but are the research establishment that implements the DOD's and Army's policies. Until a requirement is generated, the R&D labs will only work on those limited areas which are in harmony with their requirements.

Mr. Maurice E. LePera, Chief, Fuels & Lubricants Division, was interviewed on the current direction that R&D was

taking and on the policies of both the Army and the DOD. The R&D efforts will be covered in a later chapter. The most important fact discovered was the answer to the question, "What is the current DOD policy on developing alternative fuels for mobility?" Mr. LePera's answer was, "There is no DOD policy in the area of alternative fuels." When questioned on this answer, he reaffirmed that to the best of his knowledge, no policy was in existence.

DEPARTMENT OF DEFENSE: The Deputy Under Secretary of Defense for Research and Technology, Dr. Ruth Davis, was interviewed. When asked the question on current DOD policies on developing alternative fuels for mobility, her answer was, "Several months ago the Secretary of Defense directed a task force be formed to look at the problem of our reduced availability of conventional petroleum products. The first report of this task force on alternative fuels has been submitted and approved. The second phase is in progress and a policy should be forthcoming sometime in the summer of 1978."

The conversation indicated that currently there is no DOD policy, but the deficiency has been identified and is in the process of being corrected. The direction this policy takes will have a major impact on the military and the nation as a whole. Since no policy has been established by top management in the DOD, the next source to look at is the lower levels to determine if a policy has in fact been established at the "working level."

THE U.S. ARMY: The Army has listed several steps

which is the basis of its policy. The following list of goals for the Army was published in the spring of 1978 in the "Military Engineer" Magazine.

1. Reduce annual growth in energy use to less than two percent.

2. Reduce gasoline consumption by ten percent.

3. Reduce oil imports from 16 million barrels per day to 5 million barrels per day.

4. Create a strategic petroleum reserve of one billion barrels.

5. Require insulation in all new houses and upgrade ninety percent of existing ones to minimum standards.

6. Install solar energy in 2.5 million homes.

7. Reduce energy consumption per square foot in existing buildings by twenty percent and in new federal buildings by forty-five percent (using 1975 as a base year).

8. Conserve energy while maintaining military readiness.

9. Maintain zero growth based on FY 1975 total energy use.

10. Maintain liaison with other authorities and agencies in new source development.[1]

It is worth noting that the first seven steps of this policy is taken from the federal goals stated by the Carter Administration, and the last three are the Army's addition to those goals.

NATO AND OTHER COUNTRIES: In January 1975, the NATO Defense Research group met to discuss long-term scientific studies on military fuels. This demonstrates the multinational concern for the effect the dwindling fuel supply is having on defense. The summary of their findings are as follows:

> It seems almost certain that future fuels for military vehicles will be liquids. In the modern term, they will tend towards wide-cut natural hydrocarbons, then synthetic hydrocarbons or hydrogen/alcohol. Lower octane and celane values may result. The fuel tolerance of both conventional diesel and spark ignition engines is limited, and past efforts to give a true multi-fuel capacity to the conventional diesel have met with mixed success. To give a wider capability, the stratified charge engine (SCE) is considered the strongest contender in the modern term for powers up to at least (classified). In the longer term, the sterling engine, with its higher efficiency may find a place in vehicles up to (classified), but its initial cost will slow down its rate of acceptance....Because of its wide fuel tolerance, the gas turbine must remain a strong contender for the highest powered military vehicles. Failing this, the stratified charge engine, in conjunction with a boost engine, deserves consideration. There may be a case for battery propelled vehicles for short journies such as local camp transport...The consumption of petroleum-based fuels at military facilities for heating and utilities constitute a significant portion of the total energy demand relative to ground requirements. Although hydrogen does not possess the desired characteristics for use on vehicles, fixed facilities present a viable alternative for the future application of hydrogen.[2]

This report also recommended a multi-national and inter-service agreement be reached on fuel specifications and requirements.

In other countries, government concern for this area is evidenced by their commitment to develop a viable alternative to petroleum-based fuels. Sweden, though not directly involved in the embargo of 1973-74, became deeply concerned and aware of the limited supplies which seem certain in the future. The Swedish supply situation is even more sensitive since they have no domestic oil, coal, or natural gas resources. The government of Sweden has concluded that it must establish production of synthetic fuel such as methane, which, in time of crisis, can use domestic raw materials such as wood chips, peat and other organic material. The Swedish

government and AB Volvo established a joint technological development company to investigate methanol as a fuel, both in mixtures with petroleum and in pure form.[3] Brazil is already using mixtures of petroleum and methane for all domestic transportation. These countries have gone beyond the policy step and are now implementing their policies to insure the industrial base to supply fuel not only to their defense establishment, but also to its civilian population.

Work has now begun in countries throughout the world to develop other alternative fuels such as hydrogen. Although no figures were found to indicate the magnitude of the effort, Australia, Brazil, Canada, England, France, Japan, West Germany and the USSR are all working on application of hydrogen as a possible alternative fuel.

EVALUATION OF THE POLICY: A review of the literature and interviews with policy makers and the agencies responsible for implementing policy, confirmed the author's assumption that there is no formal alternative energy policy in the Department of Defense. There is R&D effort in the area of alternative fuels, but without a policy, this work lacks the direction necessary to solve technological problems.

With this in mind, a review of our present R&D efforts might shed additional light on what direction our DOD policy might take in the future. Questions which must be addressed, now, can only be answered through a centralized policy and R&D effort. Examples are:

Can the XM1 turbine be converted to hydrogen, methanol or other possible fuels?

What power plant should the Army purchase to power the Infantry Fighting Vehicle?

These are only two examples, but they point out the necessity of a central DOD policy.

REFERENCES

[1]J. W. Morris, "Energy, No Magic Solution," The Military Engineer, Vol. 70, No. 453, January-February 1978.

[2]Maurice E. LePera, "U.S. Army Trip Report on NATO Defense Research Group Panel on Long-term Scientific Studies --Multi-national Exercise on Military Fuels," (January 13-17, 1975).

[3]"Swedish Methanol Development Company," Position Paper (February 10, 1977).

CHAPTER 4

REVIEW OF CURRENT ALTERNATE ENERGY TECHNOLOGY

It is critical for our national survival that we, as a nation, develop some alternative fuel to replace the dwindling petroleum products upon which we are so dependent. This being the case, a review of the current technology must be undertaken. Though each of the sources reviewed has its own potential to make contributions to the overall energy solution, this chapter will be focused on additional R&D requirements needed to enhance these contributions.

Coal

COAL AVAILABILITY: Even though coal is a finite fuel, it is important because it could have a very significant impact on the fuel available on the future battlefield. Coal makes up a majority of our fossil fuel reserves. The total coal resources in the United States are estimated to be 3.2 trillion tons. This is 850 times the total U. S. energy requirements for 1970.[1] Besides being a source to reduce civilian consumption of petroleum-based fuels, it has many other technologically feasible uses. Two of the most promising are liquification and gasification.

GASIFICATION: The gasification process changes the solid state of coal to three gases: carbon monoxide (CO), methane (CH_4), and hydrogen (H_2). Methane, the primary

component of natural gas is similar to natural gas in heating value. Carbon monoxide and hydrogen are approximately equal in heating values to methane and natural gas.[2] Several systems have been prototyped and the results of these indicate that gasification could result in an economical and technologically-feasible alternate fuel in the near future.

LIQUIFICATION: The liquification process extracts a synthetic hydrocarbon fuel using a solvent extraction process. This process was used by the Germans during the 1940's to keep their war machine moving after conventional fuel supplies were destroyed. This process is a reality today and a small plant is now producing 15,000 barrels of solvent per day. The main problem with both the liquification and gasification process is the overall efficiency. (See Table 2)[3]

Table 2

A Summary of Overall Coal Process Efficiencies

Process	Efficiencies (%)
Liquification	62 to 69
Low BTU Gasification	65 to 95
High BTU Gasification	54 to 68

TECHNOLOGICAL REQUIREMENTS: Even though there are major ecological problems in the recovery and processing that must be considered, the major concern is the characteristic of the fuel gained through the various types of processing. The fuel that is obtained from this process varies

according to the process used. Therefore, use of this source of energy will require a decision on what process will be used. Subsequently, standardization of the engines that will turn this fuel can then be addressed.

Coal is extremely plentiful when compared to petroleum. It will solve a portion of the United States shortage problems. Several R&D problems must be overcome before the fuel developed from coal can be used as either a transportation fuel or a combat fuel for the weapon systems of the future.

Oil Shale

OIL SHALE AVAILABILITY: Oil shales located in the western United States are a potential source of vast quantities of liquid fuel. Although efforts in the past to develop oil shale technology have failed, the current status of economics and technology leads to more optimism for the future. Like coal, oil shale can produce several by-products after processing. Estimates of the United States reserves from this source is put at 600 billion barrels of oil. In this estimate, only shale ten feet thick and yielding at least 25 gallons of oil per ton was considered.[4]

TECHNOLOGICAL REQUIREMENTS: The major problem in the production of oil from shale is the adverse environmental effect directly associated with oil shale processing. These adverse effects are burned shale trailings, contaminated water, and gaseous atmospheric pollution. A major R&D

effort is required to solve these environmental problems to make this source of energy acceptable to the ecology-minded public. If the ecological problems are solved, then the refining and extraction process must be decided on, so engine modifications and design described under the use of liquified coal can be completed to permit use of the new fuel.

Table 3

Shale-oil Deposit in the Green River Formation*[5]

	Billions of barrels of oil in place			
	Colorado	Utah	Wyoming	Total
Interval 10' thick averaging 25 gal. per ton of oil	480	90	30	600
Intervals 10' or more thick averaging 10-25 gal. per ton	800	230	400	1,430
Total: Interval 10' or more thick averaging over 10 gal. per ton	1,280	320	430	2,030

Even though oil shale represents a significant contribution to alleviate future shortages, much more research must be accomplished before it will have any major impact. Government stimulation is needed to encourage research necessary to develop this source of energy. Industry does not

*Note: Over 2 trillion barrels of oil are locked in known shale-oil deposits in the Green River Formation, but less than one-third of this is in reasonably thick deposits which average more than 25 gal. of oil per ton of shale; only these are generally regarded as potentially exploitable.

seem willing to invest its capital until some guaranteed market is available. These problems must be addressed and solved if fuel from oil shale is to be a reality.

Hydrogen

HYDROGEN AVAILABILITY: As early as 1972 as many as 2000 automobiles were powered by gaseous fuels.[6] The most common gaseous fuel is natural gas. However, since 1975 a shortage of natural gas has developed, making it unacceptable to plan on the use of natural gas for transportation as an alternate fuel.

Hydrogen gas is the most plentiful of all combustibles, which makes it the most logical candidate for future use. In the past, hydrogen has been produced from natural gas. This source is being depleted, which means the future source will require electrolysis or some other process yet to be developed by our technology. Some researchers feel that hydrogen will be competitive with gasoline and diesel fuel by the early 1980's.[7] Most proposals for a so-called "hydrogen economy" emphasize its superiority to electricity for many large-scale energy applications such as transportation, space heating, and heavy industry.[8]

The Institute of Gas Technology has estimated that 60 trillion cubic feet of hydrogen would provide the energy equivalent of the United States natural gas consumption in 1968. The electrolysis production of that amount of gas at current efficiencies would require more than one million megawatt of electricity which equates to three times the

present U. S. capacity. Replacing fossil fuels with hydrogen for all uses except electricity generation, would require 295 trillion cubic feet by the year 2000.[9]

Hydrogen, with its almost unlimited supply potential and its extraordinarily clean combustion properties, could emerge as an operationally practical, economically feasible energy source. It has been shown that hydrogen can be economically produced in quantities great enough to power the automobiles of the world for the foreseeable future.[10] More importantly, it can be used in existing internal combustion engines, yielding unprecedented efficiencies and extremely low levels of exhaust pollution.[11]

The major problem with hydrogen, and the reason it isn't in widespread use, is its storage requirements. Technology has yet to develop an inexpensive, compact, lightweight method of storing hydrogen.

HYDROGEN AS A TRANSPORTATION FUEL: The DOD's main interest in hydrogen would be for ground vehicles, aircraft, and fuel cells. DOD and the military services have historically made use of commercially available fuels. This would restrict the use of hydrogen until it is developed and used in commercial quantities in the civilian community.

When looking at hydrogen as a fuel for ground combat vehicles, Table 4 (Ground Vehicle Fuels) shows that hydrogen offers several desirable properties as a fuel.

Hydrogen burns efficiently, allowing combustion in chambers with high surface-to-volume ratios. It can be

derived from water; though not always available, it is one of the most abundant resources available world-wide. The products of its combustion are water and nitros oxide. Contrary to popular opinion, it has good safety properties. It is non-toxic, non-corrosive, and, if accidently released, it disperses quickly into the air.

Table 4

Ground Vehicle Fuels[12]

Property	Civilian Concerns	Military Concerns
BTU_{vol}	Low	High
BTU_{wt}	High	High
Cost	High	Low
Emissions	High	Low
Safety	Low	High
World Availability	Low	High

Fire safety and foreign availability are two of the most important properties for combat fuels that differentiate hydrogen from conventional fuel used by commercial sector. The ratings given each of the properties are argumentative and only represent a starting point, since hydrogen has not been formally tested as a combat fuel by the Army.

HYDROGEN STORAGE: Hydrides are compositions that hold hydrogen until heated. Hydrides' major disadvantage is

weight. A vehicle would require a fuel tank twice as long and five times as heavy to carry the fuel necessary to travel the same number of miles. Figure 4, (M-60 Tank as Modified for Various alternate Fuels), demonstrates the increase in size and weight for each alternate fuel. The impact that increased fuel volume will have is reflected in the vehicle's overall size and weight. One of the major arguments against the use of hydrogen is that the added weight would cause the weight of a tank to exceed the existing bridge load limitations. Interestingly, this excess weight/bridge load limit prevented the United States Department of Army from buying the Christy Tank in the early 1930's. This resulted in the U. S. being far behind in tank design at the beginning of WWII. The greater length could also reduce the vehicle's maneuverability. As a result of these disadvantages, the DOD has concluded that:

1. Hydrocarbons represent the best chemical system to store and utilize hydrogen as a fuel for military ground vehicles.

2. Additional R&D is justified on methods to synthesize hydrogen into desirable hydrocarbons.

3. The source of carbon is a major limiting factor in the synthesis of hydrocarbon from hydrogen.

4. R&D is therefore needed not only on synthesis methods, but also on methods by which carbon can be made available in desirable form from existing abundant sources such as air, ocean water, vegetation and coal.[13]

RESEARCH REQUIREMENTS: Since the main objection to the use of hydrogen as an alternate fuel seems to be centered on storage problems, a look at what research is being done

M-60 TANK AS MODIFIED FOR VARIOUS ALTERNATE FUELS[a]

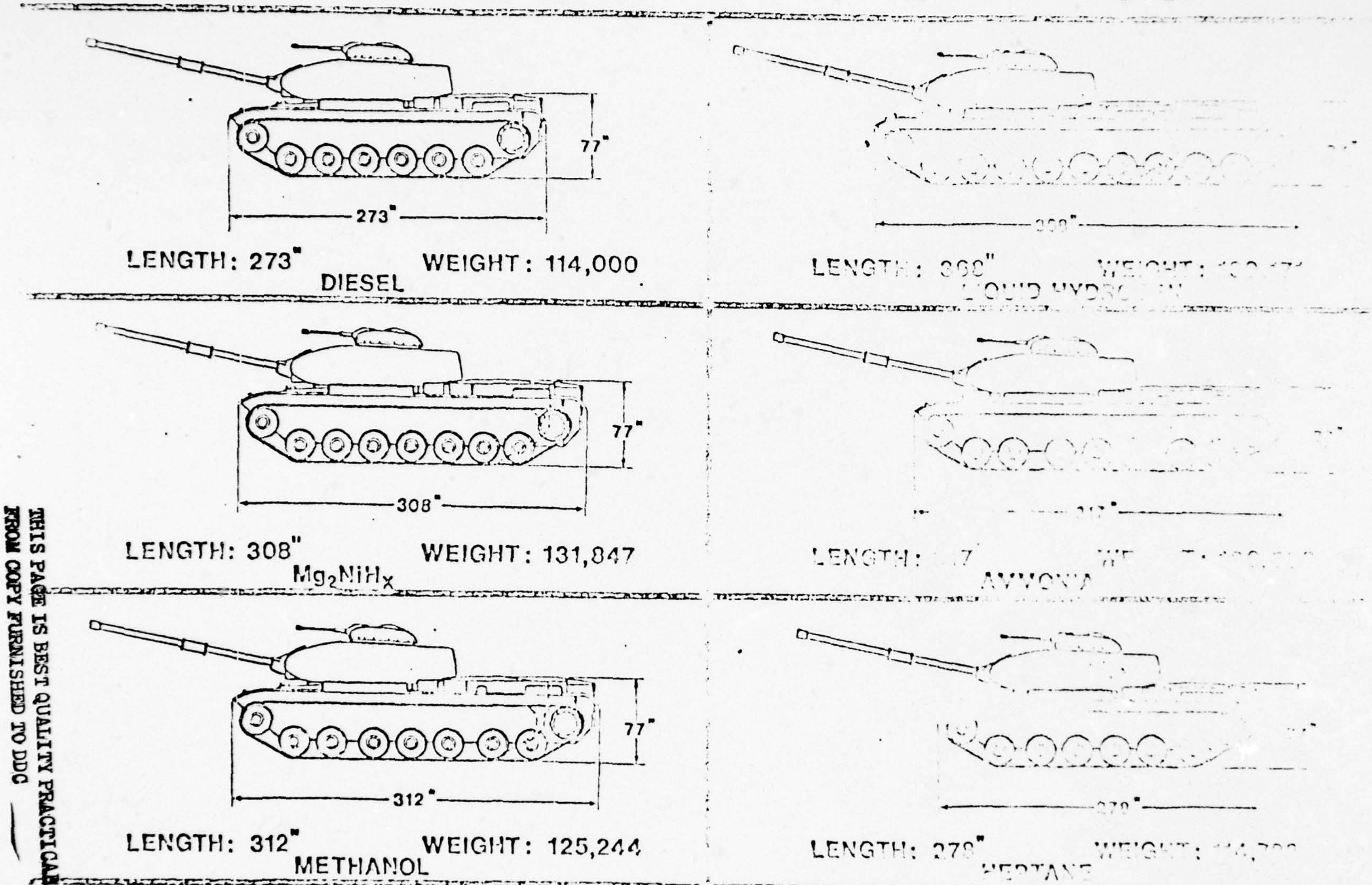


Figure 4

a. DOD paper, "Application of Hydrogen Energy to Ground Vehicles," Presented at Project Theme Confrence, Miami, Florida, 1975

to overcome these disadvantages would be in order. There has been research into this area by private industry, and some progress has been made.

Table 5 (Hydrogen-Based Fuels Comparisons) shows the relative properties of the comparative heating values, fire safety, and foreign availability.

Table 5

Hydrogen-Based Fuels Comparison[14]

Type of fuel	BTU/Lb	BTU/Ft^3	Safety	Availability
Hydrogen Gas @2000PSI	51.6	35	Poor	Good
Hydrogen Liquid at NBP	51.6	230	Poor	Good
Hydrides				
Magnisium-nickel	4.4	480	?	?
Nitrogen	8.0	385	Fair	Good
Heptyl	19.2	821	Fair	?
Methanol	19.2	429	Fair	Good
Kerosene-Typical	~19.2	~1000	Good	Good

In the 1960's researchers at Brookhaven National Laboratories suggested the use of metallic hydrides for hydrogen storage.[15] Since that initial study, many companies are experimenting with hydrogen powered vehicles. Table 6 (Current U.S. Hydrogen Vehicles Research) demonstrates the interest in this field.

Various studies have been conducted and are still in the process of refining various techniques of storing hydrogen

aboard vehicles. Initially the emphasis was on storage in high-pressure gas cylinders. However, hydrogen is very difficult to compress; and because of its low viscosity, it leaks through conventional compressor seals. Also, hydride hydrogen storage has the weight disadvantages listed earlier in this chapter.

Table 6[16]

Current U.S. Hydrogen Vehicles Research

	Engines	Vehicles
Rillings Energy Research Corporation	18	6
Brookhaven National Laboratory	1	
University of California at Los Angeles	7	2
Cornell University	2	
University of Florida	1	
General Motors Research Laboratories	3	1*
International Ecological Systems Corporation	1	1
University of Illinois	1	
Jet Propulsion Laboratories	4	1*
Los Alamos Scientific Laboratory	1	1
Matin-Marietta Corporation	1	
University of Miami	2	1
Oklahoma State University	4	
Perris Smogless Automobile Association	3	2
Totals	49	15

*Hydrogen addition to gasoline

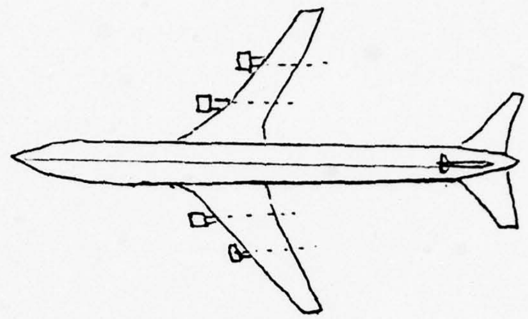
The final method of storing hydrogen is in liquid form. In the first analysis, cost seems to be an inhibiting factor. Presently liquid hydrogen costs two to three times as much as gaseous hydrogen. Hydrogen liquification requires extremely low temperatures of -400° (33°K). In addition to the expensive initial investment for cryogenic (super-insulated) containers that are required to store liquid hydrogen at these remarkably low temperatures, the problem of "Flash-off" and "Boil-off" must be considered. When a hydrogen vessel is initially filled with hydrogen, a large volume of the gas is "flashed-off" during a process in which the inner part of the tank is cooled to the very temperature of liquid hydrogen. Later, after the tank has been charged, heat leaks through the "super insulation," "boiling off" hydrogen at a rate which is reflected by the quality, and hence, the cost of the container. Although this problem can be overcome when using hydrogen as an aircraft fuel, the prospects of using cryogenic hydrogen storage for on-the-ground vehicular transportation presently does not hold great promise.[17]

HYDROGEN AS AN AIRCRAFT FUEL: Hydrogen is the lightest chemical fuel known to man. Consequently, in its liquid form it appears to have good potential as an aircraft fuel. Table 7 compares the total weight of three aircraft using conventional JP fuel and liquid hydrogen.

Liquid hydrogen suffers some disadvantages in the area of compactness. Figures 5 and 6 graphically illustrate the magnitude of the storage problem and methods which may

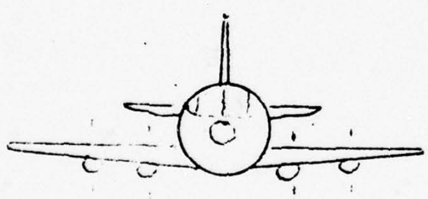
Figure 5

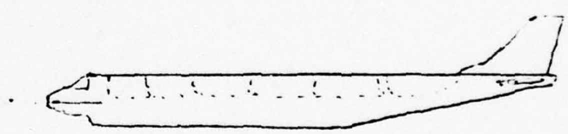
Hydrogen Configuration with Fuel Storage in Fuselage [18]



Performance Data-368 Passengers

GWE	408,932	Fuselage Length	270.00 ft.
Payload	77,000	Fuselage Depth	25.75 ft.
Fuel	107,000	Fuselage Width	24.00 ft.
TOGW	592,932	Wing Span	165.80 ft.
Range	4,978	Thrust/Weight	.28
Mach No.	.82	Thrust	40,900 Lbs/Eng.
		Energy Req'd	2,654 BTU/Pass Mi.





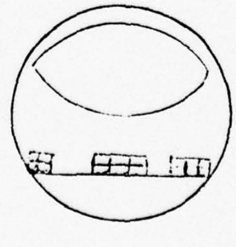
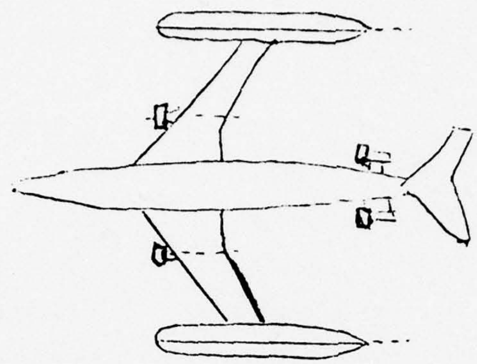


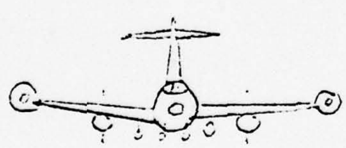
Figure 6

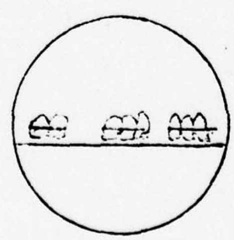
Hydrogen Configuration with Fuel Tanks in Nacelles and Wing Panels[19]



Performance Data-368 Passangers

GWE	392,439 lbs	Fuselage Length	227.70 ft.
Payload	77,000 lbs.	Fuselage Depth	22.30 ft.
Fuel	115,055 lbs.	Fuselage Width	21.25 ft.
TOGW	584,494 lbs.	Wing Span	166,00 ft.
Range	4,992 n.m.	Thrust/Weight	.308
Mach No.	.82	Thrust	45,000 lbs/Eng.
		Energy Req'd	2,726 BTU/Pass Mi.





be employed for containing the bulky fuel. This is accomplished by placing fuel storage in the upper part of the fuselage, (see Fig. 5) while placing the passenger compartment down into the area that is used for baggage in today's aircraft. Another alternate approach is the use of wing-tip tanks (Fig. 6) for necessary extra storage space. One obvious advantage in this approach is that the fuel tanks are further removed from the passenger compartment.

Table 7[20]

A Comparison of JP Fuel Airplanes and Liquid Hydrogen

	Boeing (1)		Lockheed (2)		Convair (3)	
Payload/lbs.	123,000		56,000		40,000	
Range/miles	5,000		3,400		3,000	
Mach number	.86		.82		.80	
	JP	LH_2	JP	LH_2	JP	LH_2
Take-off wt.	775,000	574,000	430,000	318,000	285,740	201,000
Fuel/lbs.	268,000	90,500	137,000	46,650	88,775	26,500
Wingspan/ft.	195	195	155	140 +tiptanks	139	116.5

HYDROGEN COSTS: When considering the cost of hydrogen in comparison with other fuels, hydrogen costs seem to be narrowing the gap. Presumably, as natural gas and petroleum supplies dwindle, our energy needs will be supplied largely from our immense coal and oil shale reserves. A recent study by Industrial Gas Technology (IGT) concludes that coal-

generated hydrogen is the most attractive near-term alternative to natural gas reformation and electrolysis. Other means such as thermochemical water splitting, photodecomposition of water and biochemical hydrogen production have not yet been developed to a point of being practical.[21] The U.S. has no operating coal gasification plants now producing hydrogen on a commercial scale. The cost of hydrogen in this form must be estimated. Estimates by experts in the field of hydrogen (Industrial Gas Technology, Fyring Research Institute, Erron and Kippers) completed in January 1977, place the cost of hydrogen roughly at $4.63 ± 25% based on Western coal, priced at $15/ton, and a plant that processes at least 2,000 tons of coal per day. Western plants currently under consideration are at least 10 times larger. The Billings Energy Corporation averaged several estimates and believe the cost to be closer to $3.37.[22] With the price of other fuels rising at astronomical rates throughout the United States, the January 1977 estimates vary from a low of $1.21 in Utah to as much as $4.85 in New York. Other cost factors estimated are: Synthetic gasoline produced from coal is going to be 1.5 times more expensive than gasoline produced from petroleum. Methanol will be more expensive than synthetic gasoline but less expensive than ammonia derived from coal. It seems unlikely that ammonia will find use as a transportation fuel because of its high cost. Both hydrogen and methanol gases costs are higher than today's fossil fuels. However, they are comparable to, or less than electricity prices in most

parts of the United States when the cost of end-point delivery is considered. For example, the electrolysis of hydrogen (hydrogen produced by electrolysis) is priced from \$4.50 to \$4.80/million BTU and could be delivered using existing natural gas systems at a price in the \$5.00 to \$9.00/million BTU range, while the current residential sale price for electricity is \$10.56/million BTU average across the country.[23]

RESEARCH REQUIREMENTS: There are many questions and gaps in technology that must be addressed before hydrogen becomes a viable fuel to power combat vehicles. There are indications that this source of energy may become a fuel alternative in the future.

Nuclear Energy

NUCLEAR ENERGY AVAILABILITY: Present military use of nuclear energy is mainly for weapons although the civilian use of this energy source releases more petroleum fuel for military use. The military also has nuclear power generators that are used to generate electrical power. Review of the Atomic Energy Commission Handbook indicates that the major use of nuclear energy in the near future will be in the production of electricity. One of the more serious problems with this energy source is its dependence on nuclear fuel U-235, PU-239, and U-233. These elements are by-products of uranium ore. It takes a ton of uranium-bearing ore to produce 0.03 pounds of U-235.[24] Because of the tremendous quantity of ore required to retrieve the elements necessary

to fuel reactors, it is estimated that our uranium reserves will be exhausted early in the 21st Century. Table 8 reflects the estimates this reduction of availability will have on the supply-demand-cost cycle.

Table 8[25]

U_3O_8 Needed for Projected Reactor Capacity

Date	AEC Projected Nuclear Capacity(MWE)	Tons of U_2O_8 Needed per Year	$8	(*) $10	$15
1974	28,183	5,367	49	60	92
1980	102,000	20,400	13.5	16.5	25.5
1985	250,000	50,000	5.5	6.8	10.4

*Number of years of proven reserves will last at the given nuclear capacity at various costs to recover uranium ore.

To overcome this projected shortage of nuclear fuel, the reprocessing of atomic fuel is being considered. Presently, because of technological and political problems, none of the three reprocessing plants now being constructed are scheduled to go into production. Once the political and ecological considerations are solved, these plants will be able to satisfy reprocessing needs of all fissionable materials well into the 1980's. Another solution is the Liquid Metal Fast Breeder Reactor (LMFBR).

THE LIQUID METAL FAST BREEDER REACTOR: The LMFBR energy resource depends on the total uranium resource base. The main difference is that the Light Water Reactors (LWR)

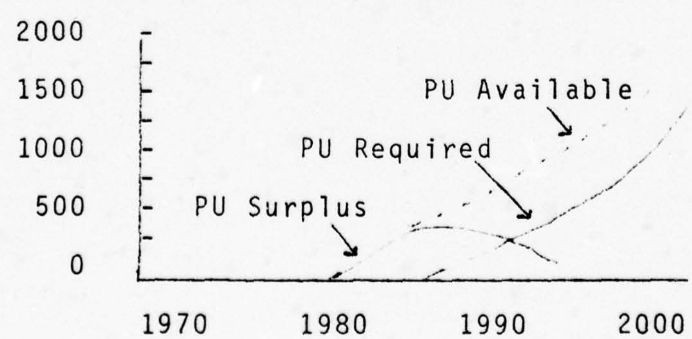
systems use U-235 isotope. This isotope occurs only 0.71 percent of the time in naturally occurring uranium ore. Since the LMFBR utilizes the U-238 isotope which comprises the remaining 99.29 percent of naturally occurring uranium, it utilizes a total energy resource base many times larger than the U-235 isotope used in the LWR energy base.

The LMFBR system will require initial plutonium inventories to operate until generated plutonium supplies are sufficient to supply needed fuel. This initial plutonium must come from the LWR systems. Thus, plutonium sufficiency will be met by the excess quantities produced in the LWR economy.[26]

Figure 7 is a projection of plutonium availabilities and requirements.

Figure 7

Plutonium Availability and Requirements[27]



The LMFBR inventory requirements do not exceed the plutonium available from LWR's until the year 2000, at which time excess plutonium from LMFBR's will provide the fuel

inventory necessary for new plants. This source of energy could reduce the dependence of the civilian economy on petroleum and natural gas. It could also provide the energy necessary to create cheap hydrogen from electrolysis, to generate the heat necessary for coal gasification and liquification, or in supplying energy necessary to process shale oil.

Solar Energy

The energy from solar sources will be divided into four categories: radiation, wind, organic fuels, and ocean thermal gradients. Each of these has its own unique characteristics and potential as a source of new energy.

RADIATION: The sun produces roughly 18,000 times as much energy through radiation as all the man-made devices currently in use throughout the world.[28] This energy can be used to heat an object directly or transfer heat to an ultimate receiver. It can also be used through photovoltaic cells in the conversion of radiation energy directly to electrical power. By use of various parabolic reflectors and concentrating solar radiation energy to a focal point, temperatures of 5000°F may be attained. Use of this technology to convert water to steam to drive turbines and generate electricity is technically feasible.

The major difficulties in the conversion of radiation energy is the relatively low density of the sun's radiation found at the earth's surface. Other problems with this

source of energy are the conversion efficiencies and the intermittent nature of sunlight due to the earth's rotation and weather patterns. To overcome the problems of low density radiation conversion efficiencies, large collectors covering many square miles are required. This requirement for large tracts of land and the corresponding high capital investment is currently preventing this source of energy from becoming economically feasible. The problem of the intermittency of solar radiation must also be solved. One solution is to provide a means of storing solar heat for subsequent use during the time no solar radiation is emitted.

Many projects are underway in the area of solar heat storage in the civilian sector. One which is showing some promise is the use of photo chemicals to store heat that is released at a later time using a catalyst. A major technological breakthrough is needed in this area before solar radiation could become a major contributor to the United States energy needs.

PHOTOVOLTAIC CELLS: Photovoltaic cells convert solar radiation directly to electrical current. This is one source of power already developed and having an impact on the economy and the defense establishment. Photovoltaic cells power satellites for reconnaissance and communications. The cost is beyond what can now be borne by the general public. This form of energy is also limited by the intermittency of the sun. To avoid the loss of radiation due to atmospheric

attenuation and nighttime outages, proposals have been made to place large arrays of solar cells in near-equatorial synchronous orbit, where the sun would shine on them 100 percent of the time.[29] The power obtained from the array would then be converted to microwave, beamed to receivers on the surface of the earth, and converted back to electrical power. This concept would require 32 square kilometers of solar cells in space at each of the stations and an area of 55 square kilometers for each ground receiving station. The output of these stations is estimated to be 10,000Mwe. This source of power, though theoretically feasible, lacks the resolution of many technological and economic problems associated with this source of energy.

WIND: Wind could supply 5.1×100^{15} BTU's by the year 2000 (NSF/NASA Solar Energy Panel 1972:50). That is close to the total electrical demands in the United States in 1972.[30] The components of a wind-power generating system have relatively modest technological requirements by today's standards. The major problem with this source of energy is the intermittent nature of the wind.

ORGANIC FUEL: Solar energy also makes possible organic tissue which will generate approximately 7,500 BTU's when burned. A ton of dry biomass can produce 1.25 barrels of oil, 1,200 cubic feet of medium BTU gas, and 750 pounds of solid residue with a heat content roughly equal to coal. By adjusting the process temperature and pressures, the relative amounts of solid, liquid, and gas generated can be

varied to meet the end-use specifications. Although the growing of plants for conversion to other energy sources is attractive, it is relatively inefficient. The solar conversion efficiency of photosynthetic process is seldom over one percent per year. This equates to a requirement for more land to produce the same energy output when compared to other solar power sources. Based on 10 to 20 tons of biomass per acre per year, the land required for a 100 megawatt organic fire-powered plant would be somewhere between 25 and 50 square miles.

The development of algae as an energy biomass has also received some attention. High productivity has been demonstrated under controlled conditions, but harvesting and dewatering represent major obstacles.[31] Reprocessing of municipal refuse, manure, agriculture waste, logging wastes, and waste manufacturing residue, sewage sludge, and some categories of industrial waste could be combined with biomass plants to generate alternate fuels. Today the use of land to produce and convert biomass crops to power, cost between $.80 and $1.20 per million BTU's; coal is $.79; domestic oil $.87; and industrial gas $.43. The crop value per acre would be somewhere between $180 and $300 which is comparable to the dollar yield from wheat acreage in the Midwest.[32] This source of energy could provide part of the solution to our problem of dwindling fossil fuels.

OCEAN THERMAL GRADIENTS: The last source of solar energy is the ocean and its various thermal gradients. The

amount of continuous energy available from ocean thermal gradients is many times more than that consumed throughout the world today. The basic theory is: because surface and depth temperatures in the area of the Tropic of Cancer and the Tropic of Capricorn varies from 77° on the surface to 41° at a depth of 3,280 feet, using a medium that boils at 68° you can generate vapor to power turbines for electricity and then condense the vapor to its original liquid state by using heat exchangers in the cool, deep ocean water. There are numerous technological developments that would be required before this source of power becomes available. Pumps, turbines, and ducting, designed to resist corrosion of salt water, are all in need of development. Another problem is the transmission of power generated hundreds of miles from land. Ecological considerations such as effects on marine life by changing the temperature of the water by the use of heat exchangers also require study.

SUMMARY: Solar energy has unlimited potential once the problems mentioned are solved. The main use of solar power looks to be one of supplementing civilian electrical heating needs, thus freeing petroleum products for use by the military. Having looked at the status of current alternate fuel technology, the next chapter will review current DOD efforts in the area of alternate fuel research.

REFERENCES

[1]The Science and Public Policy Program, University of Oklahoma, Energy Alternatives: A Comparative Analysis, 1975, p. 1-68.

[2]Ibid p. 1-66.

[3]Ibid p. 1-72.

[4]Gerald U. Dinneen and Glenn L. Cook, "Oil Shale and the Energy Crisis," Reprinted in Perspective on Energy, Edited by Lon C. Ruedeseli and Moffis W. Firebaugh, Oxford University Press, 1975, p. 377.

[5]Ibid p. 380.

[6]Linde Division of Union Carbide Corporation, "Survey Study of Efficiency and Economics of Hydrogen Liquification," Contract NAS 1-13395, NASA Hampton, Virginia, April 8, 1975.

[7]J. B. Prangborn and T. Donakowski, Industrial Gas Technology, (IGT), "Hydrogen Automotive Fuel: Production and Delivery," SEA Paper No. 760568, June 1976.

[8]Ibid.

[9]Rodney B. Beyer, "Refueling Hydrogen Transit Fleet," a paper submitted to NATO/CCMS Fourth International Symposium on Automotive Propulsion Systems, Washington D. C., (April 17-22, 1977), 3.

[10]R. E. Billings, "Hydrogen's Potential as an Automotive Fuel," Billings Energy Research Corporation, 1973.

[11]R. E. Billings, and F. E. Lynch, "Performance and Nitric Oxide Control Parameters of the Hydrogen Engine," Pub. #73002, Billings Energy Research Corporation, (April 1975).

[12]DOD Paper, Presented at Project Theme Conference, Miami, Florida, (1975).

[13]Ibid.

[14]Ibid.

[15]K. C. Hiffman, and others, "Metal Hydrides as a Source of Fuel for Vehicular Propulsion," SEA Report No. 690232, (1969).

[16]W. J. D. Escher, "Hydrogen Fueled Internal Combustion Engine, A Technical Survey of Contemporary U. S. Projects," United States Energy Research & Development Administration No. PR-51 (1975).

[17]R. E. Billings, "Hydrogen Storage in Automobiles Using Cryogenics and Metal Hydrides," Theme Conference, Miami, Florida, (March 18-20, 1974).

[18]Peter F. Korycenski, and Daniel B. Snow, "Hydrogen for the Subsonic Transport," The Hydrogen Economy, Theme Conference, Miami, Florida, March 18-20, 1974.

[19]Ibid.

[20]Ibid.

[21]Derek P. Gregory, "The Hydrogen Economy, "Scientific America, (January, 1973) 13.

[22]Beyer, op. cit., 4.

[23]Derek P. Gregory, "Hydrogen as a Means of Delivering Energy," Energy Topics, A Periodic Supplement to IGT Highlights, (December 10, 1976).

[24]Atomic Energy Commission, Division of Reactor Research and Development, "Liquid Metal Fast Breeder Reactor Program Plan." Compiled by LMFBR Program Office, Arizona National Laboratory, Springfield, Virginia (1973a).

[25]Ibid.

[26]Atomic Energy Commission, Draft Environmental Statement, "Liquid Metal Fast Breeder Reactor Program," Washington Printing Office Vol. 4, (1974a) 1-20.

[27]R. J. Criagon, "Boon to Society--The LMFBR," Mechanical Engineer, (February 1973).

[28]Encyclopedia Britanica, Chicago Encyclopedia Britanica, Vol. 20 and 21, (1973).

[29]W. C. Brown, "Satellite Power Stations: A New Source of Energy," IEEE Spectrum, (March 10 1973) 38-47.

[30]National Science Foundation/National Aeronautics and Space Administration Solar Energy Panel, "An Assessment of Solar Energy as a National Resource," University of Maryland, College Park, Maryland (1972).

[31] R. E. Inman, "Effective Utilization of Solar Energy to Produce Clean Fuel," Stanford Research Institute, Third Quarter Progress Report, NSF Foundation Grant GI 38723, October 30, 1973.

[32] Ibid.

CHAPTER 5

CURRENT DOD ALTERNATIVE FUEL RESEARCH EFFORTS

AVAILABILITY OF FUELS: The emphasis of DOD research and development programs has been oriented toward the availability of combat fuels at various locations throughout the world. The application of this effort has been to describe fuel properties that give the best compromise between performance, cost, and availability. A review of past R&D efforts in this area indicates that the compromise has been made in favor of performance. Recently a new emphasis has been stressed in the area of availability. This approach stresses excellent performance and low cost during periods of adequate fuel availability. As fuels become scarce, a new compromise will have to be reached. The choice is either one of immobility, or finding some alternate fuel, since conventional fuels will be unavailable.

The Fuels Lab is cataloging fuels and developing methods by which non-technical field personnel can utilize fuels that deviate from designed specifications of the engine fuel. This effort will also give field personnel an idea of the expected performance of various emergency fuels.

The Army R&D approach on emergency fuels is based on the premise that it will take a long lead time to secure supplies of conventional fuels. Because of this lead time, ten or more years, emergency fuels are considered existing

products that can be made immediately available when needed. They do not presently include alternate energy sources such as solar energy, oil shale or sand tar. Fuels that do qualify under this definition are crude oils, residuals, distillates and other fuels that are stored or are in transit around the world. Thus, the main thrust is to identify and adapt these fuels for emergency use.

DOD POSITION: Since all the R&D efforts mentioned thus far are basically stop-gap solutions, it is obvious that some permanent solution is needed. The DOD position is that despite the growing scarcity, long-range power plants will favor the use of conventional fuels on the assumption that methods will be developed to produce supplemental amounts of good quality fuels at or near the site of combat.

ARMY POSITION: In 1975 the DOD and the Army initiated a very limited program. The following list identifies where the initial effort was made.

1. An evaluation was initiated to determine the potential quality of liquid fuels from various coal liquification methods.

2. Examined the potential quality of substitute fuels produced from mobile crude refining methods.

3. Conducted turbine combustor studies on hydrocarbon fractions which are considered representative of future synthetic fuels.

4. Developed models of power plants and fuel systems when using hydrogen in gaseous liquid and solid (hydride) states.

5. Determine the maximum potential of hydrogen release and recharge from various hydride compositions.[1]

The direction now being pursued by the Army Fuels Laboratory is to identify and test fuels that can be used in combat vehicles and tactical equipment without any degradation in performance, range, safety, or engine reliability. This approach requires a detailed analysis of each of the engines now operating in the U.S. Army inventory. Military engines have not been designed to operate on a multi-fuel specification basis. Each engine has its own fuel. As a result, the position taken in the Army is that the major effort should be on conventional fuels. Specific objectives would be to develop fuel specifications, onboard engine devices, and additives such as alcohol blends to increase conservation.

At AFLRL, work is now directed at additives which will give greater miles to the tank of fuel for combat vehicles. These additives are designed for conventional convenient petroleum-based fuels.[2]

FOREIGN RESEARCH: Some research is being conducted on the production of hydrogen. The primary area being addressed is the development of a thermochemical process using nuclear fission to produce the heat necessary in the process. The R&D in this area requires parallel development of high-temperature nuclear reactors. West Germany seems to be the leader in this field.

The USSR is doing extensive research in the area of hydrogen production and its use as an alternative fuel. In a paper published in 1977, a Soviet scientist, A. F. Sheklein observes:

According to estimates, the demand for generated power in the USA at the end of the century will be 2 million MW, requiring the construction and placing into service of more than 1500 new electric power plants with a capacity of 1000MW. If these plants were located a certain distance away from the ocean, which would reduce their influence on the environment, thus on the average they would be situated 5km apart over the entire coast of the USA, including Alaska and Hawaii. Thus, just by the year 2000, it would evidently be impossible to solve the problem of supplying energy by conventional methods, even if we neglect the size of fuel reserves.[3]

It is interesting to note at this point, that the USSR has a large staff working on applications of hydrogen to meet their energy needs even though recent estimates indicate they have three times our fossil fuel reserves. As stated earlier, many countries are interested in hydrogen as a fuel; but the world-wide research effort on hydrogen energy is uncoordinated and dispersed, both in the nature of the work and in objectives.

Experts in the field of hydrogen production are convinced that technology will reduce cost and advance efficiency to a point where hydrogen will become economically feasible. The Russian scientist, Shklein, feels that the technology for solar produced hydrogen is possible in the not-too-distant future.[4] Work in the area of photo-chemical and biological extraction of hydrogen from water is also beginning to show promise even though they are in the early stages of development.

CURRENT R&D NEEDS: When examining the research and development programs of today and comparing them to the needed technological breakthroughs indicated under the various energy

sources in Chapter 4, it is evident that additional work is needed. It is apparent that a lack of policy in the DOD is reflected by the lack of effort in the area of alternative fuels. The present efforts are not concentrated on technology needed to solve problems of developing an acceptable fuel to replace convenient petroleum products which will be depleted early in the next century.

There is a need to identify the process that will be used to liquify coal and retrieve and process petroleum from oil shale. This process must be addressed in current R&D efforts. One must recognize that the form of alternative fuels from coal and oil shale vary depending on the process; and, if engine R&D work is going to use alternative fuels, the process must be identified and pursued.

The environmental problems of mining and processing coal and oil shale also need effort. In the area of solar energy,more work on improving conversion efficiency is needed. Storage of solar energy to overcome the intermittent nature of the sun and the production of hydrogen from solar energy sources are two areas that need to be included in future R&D efforts. The work in the nuclear energy field needs to satisfy future needs while meeting public demands for an ecologically safe and acceptable means of dealing with nuclear waste.

At the same time that research and development efforts address the needs for developing alternative fuels, parallel efforts are needed in engine design. A majority of Army mobility equipment is diesel powered. This limits these

engines to the use of diesel fuel only. The development of a true multi-fuel engine must be pursued.

It is evident when looking at DOD needs, that not all research and development problems are the concern of the Defense Department. What is needed is a decision on what areas are critical to the DOD's future mobility needs, and a policy developed to give the research establishments guidance on the direction the Department wants to go in the future.

REFERENCES

[1]U.S. Army Fuels & Lubrications Research Laboratory (AFLRL), "Plans and Status of the U.S. Army Energy R&D Programs," August 1974.

[2]Ibid.

[3]A. U. Sheklein, "Solar Energy and Hydrogen Power: Present State of the Problem," (From the Foreign Press), 57-62, Reprinted in Solar Energy Update, July 1977.

[4]Ibid.

CHAPTER 6

PROPOSED ALTERNATIVE FUELS POLICY

Goals

LONG-TERM GOALS FOR THE YEAR 2010 PLUS: The United States must become energy independent if its citizens are to continue to enjoy their current standard of living. The solution is a total commitment to the goal of independence. Since petroleum products will be extremely scarce, we must develop alternative fuels which are not dependent on exhaustible resources.

SHORT-TERM GOALS FOR THE YEARS 1978 - 2010: The country must use its domestic resources to replace dwindling petroleum resources for an interim period while technology is developed to meet long-range goals. This transition period should use a combination of petroleum and synthetic fuels..

The Recommended Policy

SECRETARY OF DEFENSE POLICY STATEMENT: As the Secretary of Defense, I recognize the Defense Department cannot wait for a resolution of the problems posed by the imminent loss of petroleum-based fuels. Every possible step must be taken to insure fuel is available to U. S. Forces to maintain their mobility in a world of dwindling petroleum reserves. These alternative fuels must be obtained from domestic U. S. natural resources to avoid the transportation and economic

problems that now face the nation in the area of imported petroleum.

My proposed short-term solution is to establish a fuel transition period which begins with the implementation of this policy. During this period all DOD services and agencies will make the transition from currently-used petroleum fuels to synthetic fuels. Contracts will be established with the industrial sector to develop liquid and gaseous fuels from the nation's extensive coal reserves. The DOD will initially guarantee a market for the synthetic fuels produced as an incentive to industry to develop this important source of energy. It is envisioned that as the amount of fuel produced increases, the excess will be marketed to the public sector. The Army's Fuels and Lubrication Laboratory will work closely with industry to establish and refine requirements of the synthetic fuel. The Army's Fuels and Lubricants Laboratory will provide the combustion characteristics of the new fuel to each service, thus enabling them to purchase engines capable of burning the synthetic fuel. Upon receipt of the new fuel characteristics, each service will insure that all engines purchased or contracted for are of multi-fuel design and are capable of using the new fuel. This solution will be phased in over the next 30 years and will start from primarily a petroleum base and move through the continuum to primary use of a synthetic-based fuel.

This use of synthetic derivative is only an interim solution which will insure adequate fuel for the near term.

A long-term solution is also required. My long-term proposal to prevent a crash program from being necessary in the 21st century is to implement an extensive research and development program. This R&D program will be supervised and coordinated by my office with the Under Secretary of Defense for Research and Technology having the primary supervisory responsibility. This program will be implemented upon receipt of this policy with interim reports due a minimum of once each year. This report will measure progress made towards the long-term goal of total energy independence in the year 2010. I further recommend that initial efforts to solve our long-term requirements be in the area of hydrogen R&D. Hydrogen is one of the most plentiful elements in nature and is found in water, oil shale, and coal. The R&D efforts initially should be focused on the major problems precluding immediate use of hydrogen. These are storage, transportation, and production. Production methods using both solar and LMFBR nuclear energy should be persuaded. When we have resolved these problems, we will have resolved the energy requirements of the 21st century.

CHAPTER 7

SUMMARY, CONCLUSIONS, & RECOMMENDATIONS

Summary

The facts presented in Chapter 1 lead to the conclusion that as a nation we will be in a position where conventional fuels, as we know them today, will either be gone or will be in short supply by the year 2000. Therefore, alternative fuel sources will be required. It follows that a decision must be made and a policy established in the area of alternative fuels. The next question is: "Should the DOD have a policy of its own, considering that other governmental agencies have the primary charter to develop alternate energy sources?"

The answer to this question lies in the examination of the uniqueness of the DOD stressed in Chapter 2. The DOD has world-wide mobility requirements that are totally reliant on petroleum-based fuels. Based on the uniqueness of these requirements, the danger that conventional fuels won't be available, and that fuels are essential to enable the DOD to carry out its mission, leaves only one conclusion: the DOD needs its own alternate fuels policy.

The current policy in the area of alternative fuels was examined. If the statements of both the policy makers in the DOD and those charged with the implementation of such policies as related in Chapter 3 are true, then the DOD does

not currently have an alternative fuel policy. It was pointed out that there is a movement in this area presently which could lead to a policy sometime in the summer of 1978. Since there is currently no policy, the next step was to examine the areas of research that might indicate what direction that policy might take.

A review of the current technological requirements of several alternative energy sources was undertaken in Chapter 4. The shortcomings in the area of research and the advances needed were reviewed. The research and requirements necessary to sufficiently develop some of these alternate fuel sources to make contributions to our total energy requirements by the early 1980's was documented. Some of these sources have already developed the necessary technology, and all that is now needed are economic considerations to arrive at a point where these fuels will become economically feasible.

Chapter 5 examined the current R&D effort that has been taken. Results of research in this area indicated there has been a fragmented approach to solving the technological problems outlined in Chapter 4. A need for a central policy evolved. Chapter 6 presents a proposed DOD policy.

Conclusions

There is a serious gap in the United States national effort to develop alternate fuels. This shortcoming evolves from a failure at the national level to formulate policy and

and plans to alleviate the projected petroleum fuel shortage that was established in Chapter 1. The basic research in areas such as fuels from coal, oil shale, biomass, and nuclear energy are producing massive amounts of energy technology. This creates an impression that all the Defense Department has to do is sit back and a revolutionary new fuel will miraculously emerge as a result of the research now being conducted by the civilian industrial community. This may in fact happen. It is true that we have the technology to produce liquid fuels from our vast coal reserves and sources such as: shale oil, biomass, and waste materials. Considering this to be true, what is the problem? One theory is: If we have the technology to produce alternative fuels from coal and oil shale, then all that is needed is a rise in the cost of petroleum-based fuels to a point where alternate fuel production methods become economically feasible. This thesis is misunderstood not only by the general public but also by some of our senior policy makers. The fact is that alternate fuels that are produced from coal and oil shale will have very different characteristics when compared to current fuels.[1] These differences will require major engine modifications or possibly a complete engine redesign.

An alternate fuel program requires the investment of today's dollars to develop results which may not be felt for a decade or more. The natural approach is to spend money for something that produces immediate results. Each administration

has pressures to maximize returns on each year's fiscal budget. A continual Department of Defense philosophy of "Let industry do it," "Let the next guy worry about it" will lead the defense establishment into a position much like the crash space program of the early sixties, or yet another crisis management situation.

The present DOD effort is still based on fossil fuels. The Defense Department now seems to be grasping just how serious the fuel situation is and may well solve its shortcomings in the area of policy on alternative fuels.* Almost all current and past research has been in the area of conservation. Major addresses by senior DOD personnel still stress conservation. General Brown, Chairman of the Joint Chiefs of Staff, again stressed the conservation theme in November 1977.

> The Armed Forces account for less than two percent of the nation's energy consumption. The amount of fuel used in mobile operations (that is, consumption other than installation support) is about two-thirds of that two percent, a rather modest amount. This amount goes for operations, training and other functions contributing to readiness. The Armed Forces continue to conserve energy--between FY 1974 and 1976, consumption for mobile operation has been reduced nearly 15 percent--note it is important to national security that the modest expenditure to support mobile operations be continued.[2]

Predictions by energy experts and by Secretary of Defense, Dr. Harold Brown, lead to only one conclusion: there will not be any fuel left to conserve by the early part of the next century. Yet, with this being evident, the

*Note: Conversation with Dr. Ruth Davis, Under Secretary of Defense for Research and Technology, indicated a policy would be forthcoming.

conservation theme continues. In testimony before the Subcommittee on Military Considerations and Stockpiles, the Under Secretary of Defense for Installations and Housing stated:

> While a good part of our energy consumption is directly related to the maintenance of our forces, their training and their operational missions, there is also a significant part that goes into maintenance and operation of our facilities--actually about 35 percent of the DOD annual consumption in the Continental United States. And we recognize that we have an opportunity, indeed an obligation, to substantially reduce our energy use in these facilities through various conservation measures.[3]

Even though these conservation efforts are meeting with success, the requirements to stay within budget constraints has led to reduction in training and a potential impact on operational readiness. Reliance on continued conservation themes is not the answer. Conservation only buys time. With a finite supply of petroleum fuels, an alternate fuel is an absolute must. Failure to recognize a responsibility in the research and development area to seek alternate fuels is a major shortcoming in the present Defense Department energy position.

The Energy Research and Development Administration's strategy has placed most of its emphasis on extraction and refining of petroleum, and little on application of existing technologies towards finding alternatives to these fuels. Work on usage continues to be limited. This work consists mainly of testing and evaluating synthetic liquids, gases, alcohols, and hydrogen. R&D in this area is important as it does define adjustments that are required in the refining

processes, fuel blending and engine design. Unfortunately, most of these adjustments have caused an increase in complexity. What is really needed is a simplification of the processes to reduce cost. The fact is there is no viable national effort to develop a new fuel for either ground highway transportation or to power future combat vehicles. This has been a failure to adjust and accept the fact that we are rapidly approaching a "no-fossil-fuel world" and that alternate energy research is the only answer. The resistance to accept this as fact has placed our future national security in jeopardy.

Although the Defense Department has recognized the energy problem, a long-term plan using a systems approach is needed. The need for DOD leadership in solving the critical problem of an alternate fuel source is absolutely essential. The DOD leadership could take numerous directions, but the first step must be to set goals and a central policy as outlined in Chapter 6.

Recommendations

That the policy and goals stated in Chapter 6 be used to finalize a centralized DOD alternate fuel policy leading to energy independence by the year 2010. In order to implement this policy, the following steps are recommended:

Step 1. To support the DOD goals for the year 2010, milestones must be established.

Step 2. A determination of what fuels and sources

of energy are available for U. S. natural resources must be made. Research indicates that coal is our nation's most abundant domestic source of energy, with the most technological promise. Therefore, coal is the recommended source of synthetic fuels to be developed by the DOD.

Step 3. The transitional period from petroleum to synthetics should begin immediately and continue into the first decade of the 21st Century.

Step 4. A guaranteed synthetic fuel market should be established to promote private industry development.

Step 5. A systems approach should be adopted in the implementation of the policy. Since it has been established that fuel characteristics will differ from present-day fuels, engines must be designed to burn newer forms of fuel. The component services of the DOD need a definite area of responsibility. The responsibility for the development of various future fuel-burning engines by category should be assigned; i.e. the Army should be responsible for all ground transportation engine research and development; the Navy, all nuclear engines; and the Air Force all aircraft engines to include helicopters. These services will be responsible for coordinating and exchanging information with both industry and their sister services.

Step 6. Long-term goals must be established to carry the nation through the 21st Century. The interim measures taken during the transition period cannot supply indefinite fuel supplies. The most common element that can be used as

a fuel is hydrogen. It is, therefore, recommended that research efforts be focused on solving the production and storage problems which preclude the immediate use of hydrogen.

Step 7. Finally, the Defense Department and the administration should reevaluate its position on alternate energy research. Vast sums of money need to be invested today. The military services are uniquely capable of solving these research problems if given the charter and resources required. Immediate action is required as time is now growing short. Questions such as what fuels should be tested on the turbine engine that powers XM1? What engine will power the Infantry Fighting Vehicle: These questions are just two of the many that must be answered. Failure to develop a long-term plan and strategy for these weapon systems in the area of alternate fuels can prove to be extremely costly in the future. The success of our defense establishment depends upon the realization that we cannot wait until our economy and our national defense deteriorates to a point where we are crippled and a state of crisis exists before we act.

REFERENCES

[1]U.S. Energy Research and Development Administration, "Alternative Fuels Utilization Report," No. 3, (October 1977).

[2]Opinions expressed by General George S. Brown, Chairman of the Joint Chiefs of Staff, in an address to the Houston Club Men's Forum at Houston, Texas, (November 10, 1977).

[3]U.S. Senate, Armed Services Committee, Subcommittee on Military Considerations and Stockpiles, Testimony by Perry J. Fliakas, Deputy Assistant Secretary of Defense (Installations and Housing), (November 17, 1977).

BIBLIOGRAPHY

1. Books

Ruedesili, Lon C. and Morris W. Firebaugh. Prospectives on Energy. New York: Oxford University Press, 1975.

University of Oklahoma, The Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Norman: University of Oklahoma Press, 1975.

2. Government Papers

Atomic Energy Commission, Division of Reactor Research and Development. Liquid Metal Fast Breeder Reactor Program. Compiled by LMFBR Program Office, Arizona National Laboratory, (Springfield, VA., 1973).

Atomic Energy Commission, Draft Environmental Statement. Liquid Metal Fast Breeder Reactor Program. Vol. 4 (Washington: Government Printing Office, 1974) 1-20.

DOD Paper. Application of Hydrogen Energy to Ground Vehicles. Presented at Project Theme Conference, Miami, Florida, 1975.

Escher, W. J. D. Hydrogen Fueled Internal Combustion Engine, A Technical Survey of Contemporary U.S. Projects. United States Energy Research & Development Administrations, No. PR-51, 1975.

LePera, Maurice E. U.S. Army Trip Report on NATO Defense Research Group Panel on Long-term Scientific Studies--Multi-national Exercise on Military Fuels. U.S. Army Fuels and Lubricants Laboratory, 1975.

National Science Foundation/National Aeronautics and Space Administration (NSA/NASA) Solar Energy Panel. An Assessment of Solar Energy as a National Resource. (College Park: University of Maryland, P.B. 221659, December 1972).

U.S. Army Fuels and Lubricants Laboratory. Plans and Status of the U.S. Army Energy R&D Programs. AFLRL, August 1974.

USAF Alternate Energy Workshop, Cost of Energy. AFIT School of Engineering, Wright Patterson AFB, Ohio, February 1976.

U.S. Energy Research and Development Administration. Alternative Fuels Utilization Report. No. 3, October 1977.

3. Periodicals

Brown, W. C. "Satellite Power Stations: A New Source of Energy," IEEE Spectrum. (March 10, 1973).

Criagon, R. J. "Boon to Society--The LMFBR," Mechanical Engineering. (February 1973).

Editorial, "A Search for New Energy Takes Many Paths," Kansas City Star, Vol. 98, No. 8. (September 27, 1977).

Gregory, Derek P. "Hydrogen as a Means of Delivering Energy," Energy Topics, A Periodic Supplement to IGT Highlights. (December 20, 1976).

Gregory, Derek P. "The Hydrogen Economy," Scientific American. (January 1973).

Gillette, Robert. "Energy R&D: Under Pressure, A National Policy Takes Form," Science, Vol. 182, No. 4115. (November 30, 1973).

Morris, J. W. "Energy: No Magic Solution," The Military Engineer, Vol. 70, No. 453. (January-February 1978).

Morton, Roger C. B. "The Nixon Administration Energy Policy," American Academy of Political and Social Science Annals, Vol. 410. (November 1975).

Nixon, Richard M. "Nixon's Blueprint for Meeting the Energy Crisis," U.S. News and World Report, Vol. 75, No. 21. (November 19, 1973).

"Out of the Hole With Coal," Time, Vol. 105, No. 4, (January 28, 1974).

"When Hydrogen Becomes the World's Chief Fuel," Business Week. (September 23, 1972).

4. Papers

Beyer, Rodney B. "Refueling Hydrogen Transit Fleets," A paper submitted to NATO/CCMS Fourth International Symposium on Automotive Propulsion Systems. Washington D.C. April 17-22, 1977.

Billings, R. E. "Hydrogen's Potential as an Automotive Fuel," Billings Energy Research Corporation. 1973.

Billings, R. E. "Hydrogen Storage in Automobiles Using Cryogenic and Metal Hydrides," Theme Conference, Miami, Florida, March 18-20, 1974.

Billings, R. E. and F. E. Lynch, "Performance and Nitric Oxide Control Parameters of Hydrogen Engine," Pub. #73002, Billings Energy Research Corporation. Ogdon, Utah, April 1973.

Hiffman, K. C. W. E. Wensche, R. H. Wiswall, J. J. Reilly, R. V. Sheihan, and C. H. Waide, "Metal Hydrides as a Source of Fuel For Vehicular Propulsion," SEA Report No. 690232. 1969.

Inman, R. E. "Effective Utilization of Solar Energy to Produce Clean Fuel," Stanford Research Institute, Third Quarter Progress Report, NSA Foundation Grant GI38723. October 30, 1973.

Korycenski, Peter F. and Daniel B. Snow. "Hydrogen For The Subsonic Transport," The Hydrogen Economy, Theme Conference, Miami, Florida, March 18-20, 1974.

Linde Division of Union Carbide Corporation. "Survey Study of The Efficiency and Economics of Hydrogen Liquification," Contract NAS 1-12295. NASA, Hampton, Va. April 8, 1975.

Pangborn, J. B. and T. D. Donakowski. (Industrial Gas Technology) "Hydrogen Automotive Fuel: Production and Delivery," SEA Paper No. 760568. June 1976.

Sheklein, A. V. "Solar Energy and Hydrogen Power: Present State of the Problem," (From the Foreign Press) pp57-62, Reprinted Solar Energy Update. July 1977.

Swedish Methanol Development Company, Position Paper. February 10, 1977.